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(54) **Rate adaptive pacer.**

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EP-A-0 011 950
FR-A-2 403 775
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Description

This invention relates to cardiac pacers and more particularly to a rate adaptive pacer which alters the pacing escape interval in response to the physiologic demand of the patient.

Implantable medical devices for the therapeutic stimulation of the heart are well known in the art. Initially these cardiac pacers were asynchronous in operation providing stimulating pulses to the heart at a fixed rate independent of the physiologic demand of the patient.

Subsequently, demand pacemakers were developed as exemplified by U.S. Patent No. 3,478,746 to Greatbatch. These devices provide stimulating pulses to the heart only in the absence of naturally occurring cardiac activity. This form of pacer permits the patient's underlying cardiac rhythm to inhibit the pacemaker if the patient's intrinsic heart rate is above the preset escape interval of the pacer. However, if the patient's intrinsic cardiac activity drops below the minimum rate set by the escape interval of the pacer, stimulating pulses will be supplied to the heart. In this fashion the demand pacemaker provides a lower boundary rate below which the patient's heart will not be permitted to drop. The therapeutic benefit of such demand pacemakers was enhanced by the development of the hysteresis type pacer known from U.S. Patent No. RE 28,003 to Gobeli, which provides two escape intervals.

The hysteresis pacemaker permits the heart to inhibit the pacemaker down to a sentinel rate set by the hysteresis pacemaker. However, if no intrinsic cardiac activity is detected during the sentinel escape interval, the patient's heart will be stimulated at a nominal escape interval which is somewhat shorter than the lower hysteresis rate. In operation, the hysteresis pacer alters the escape interval in response to detected cardiac events.

More recently, pacers have been disclosed which rely upon a historical average of detected cardiac activity to set the escape interval. An example of one such pacer is taught by U.S. Patent No. 3,921,642 to Preston.

Other forms of rate adaptive pacers have also been proposed. These pacers rely on the sensing of atrial activity, blood pH, respiratory rate and QT interval data to alter the pacer's escape interval. Discussions of some of these prior art proposals may be found in *Relation Between the QT Interval and Heart Rate*, Rickards and Norman, Br. Heart J., 1981; 45; 56—61 and *A Physiologically Controlled Cardiac Pacemaker*, Krasner, Voukydis and Nardella, J.A.A.M.I., Volume I, No. 3, 1966; 14—20.

This historical progression indicates the desire to provide a pacer which alters the escape interval in response to the physiologic demand or needs of the patient.

FR—A—2 403 775 discloses a rate adaptive demand pacemaker in which the escape interval is variable and may be varied as a function of cardiac blood pressure.

U.S. Patent No. 4140132 aims to provide a cardiac pacemaker, the pulse rate of which varies as a function of the physical activity of the user. This activity is sensed using a piezo-electric device.

Viewed from one aspect, the invention provides a rate adaptive pacer having a pulse generator for delivering stimulating pulses to cardiac tissue at the expiration of an escape interval, and including means for altering the escape interval between preset limits in response to the sensed activity of the patient sensed through activity monitoring circuitry, characterised in that said activity monitoring circuitry is responsive to the frequency of the peak spectral energy of mechanical forces external of the heart.

Preferably the apparatus is arranged to alter the escape interval in accordance with the spectral characteristics of the activity signals. The preferred form of the present invention includes a force sensor located within the pacer itself.

Although this invention is disclosed within the context of a single chambered demand pacemaker (VVI), it should be appreciated that the rate adaptive feature based upon the detection of mechanical activity could be applied to any of the currently known pacing modalities including the atrial sequential pacing mode (DVI) and dual demand pacing mode (DDD).

An embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, in which:

Fig. 1 is a system diagram used for modelling the patient/pacer system;

Fig. 2 is a diagram showing the spectral characteristics of the activity signal detected by the sensor as well as the various noise signals present within the patient/pacer system;

Fig. 3 is a functional block diagram of a single chamber demand pacemaker incorporating the present invention; and

Fig. 4 is a graph depicting the operational mode of the Fig. 3 pacer.

An understanding of the invention is facilitated by a brief analysis of the patient/pacer system depicted in Fig. 1. In this diagram the patient's body 10 is modelled as a damped resonant system. A variety of mechanical forces both internal and external to the patient are applied to this damped resonant system. These force inputs are modelled by element 12 in the diagram. Forces applied to the body result in forces applied to the sensor 14 contained within the pacer generally designated 30. The raw data from the sensor system 14 is supplied to signal processing circuitry 16 which develops an activity parameter which is applied to alter the escape interval logic 40. The nature of the signal processing circuitry is discussed in connection with Fig. 2.

Data has been collected which shows that the response of the typical human body which results from mechanical activity related to the physical activity of the patient such as pedal impacts from walking or running is centered around approximately 10 Hertz. The sensor 14 located within the pacer interacts with soft tissue at the implant site and detects the various mechanical vibrations

present at that location. These forces result from the mechanical exertion of the patient which are related to the physiologic demand for oxygenated blood as well as a variety of noise signals resulting from respiration, cardiac activity, speaking and skeletal muscle noise.

In Fig. 2 there is shown a spectral analysis of the electrical signal from the sensor. Internal noise 18 due to respiration is centered at approximately 0.2 Hertz while the peak response 20 resulting from cardiac activity is centered at approximately 1.1 Hertz. Peak 18 lies below the general level of broad-band background noise 23 and peak 20 slightly exceeds it. Noise signals which result from audio signals in the patient's environment as well as noise due to the speech of the patient increase monotonically as shown by curve 22.

The physical activity which will be utilized to alter the escape interval of the pacer is shown by the characteristic activity curves 24, 26 and 28. These curves result from the excitation of the patient's body due to pedal impacts associated with walking and running and correlate strongly with the oxygen demand of the body. It is important to note from the diagram that the curves corresponding with low, medium and high activity all exceed the average noise level 23. It is also important to note that these activity curves lie within a passband which excludes respiratory and cardiac activity as well as the substantial portion of the audio frequency noise 22. The proportionality between the amplitudes of these activity curves and the physiologic demand of the patient has been verified through experiment.

As can be seen from the diagram the spectral peak of the low, medium and high activity curves shifts to the higher frequencies with higher activity levels. It is believed that this phenomenon is due to the upward shift of the spectrum of external mechanical excitation. This feature is important with respect to the signal processing parameters selected for the operation of the pacer of the present invention which is described in connection with Figs. 3 and 4.

Before leaving Fig. 2, it should be clear that the activity signals could be isolated from both high and low frequency noise sources through a filtering process which would attenuate both the respiratory, cardiac and audio components. The amplitude of this signal after bandpass filtration could be used as the activity parameter. However, it is believed that the use of such an activity parameter would be sensitive to the placement of the pacer and would be sensitive to the tissue characteristics surrounding the sensor at the implantation site. In recognition of this effect a zero-crossing detector effectively tracks the highest amplitude spectral component of the signal present within the passband of the sensor signal. Thus, it is important to note that the signal processing accomplished in block 16 of Fig. 1 first extracts the activity passband from low freqency cardiac and respiratory noise as well as separating the activity signal from high frequency audio noise. After appropriate bandpass filtering, the sensor signal is passed to a zero-crossing level detector which rejects all low amplitude signals within the passband. This feature permits the zero-crossing detector to track the spectral peak within the passband.

The level detector is followed by a circuit for producing a pulse rate signal proportional to the frequency of the peak spectral components within the activity passband. This signal is utilized by the pacemaker circuitry for altering the escape interval of the pacer.

This system is capable of extracting a meaningful indication of the physical activity of the patient from a sensor located within the pacemaker can. One application of this sensed activity parameter to a cardiac pacemaker is to utilize the activity parameter to slowly vary the rate between a programmable or preset upper and lower rate. The implementation of such a system is described in connection with Fig. 3.

In Fig. 3, the pacemaker is designated generally 30. The pacer includes a piezoelectric force sensor 32 coupled to the hermetic enclosure of the pacemaker for converting vibrational energy at the pacemaker site into a sensed activity signal. The sensed activity signal is applied to a bandpass amplifier which rejects the low and high frequency components of the applied force. This signal is also level detected producing a processed activity signal which excludes low amplitude information within the designated passband of the bandpass amplifier. This function is accomplished within circuit element 34. The processed activity signal produced by circuit element 34 is supplied to a slow waveform generator 36 which integrates this activity over a selectable time period selected by programmable slope control 37. The output of the slow waveform generator is applied to the voltage input of a voltage controlled oscillator 38 converting the integrated activity signal into a pulse rate proportional to the magnitude of the activity parameter. This activity parameter signal is supplied to the logic and timing circuitry of a conventional demand pacemaker 40 for altering the escape interval. The details of the implementation of the escape interval alteration circuitry are not provided since they are within the skill of pacemaker designers.

The escape interval may vary between an upper and lower bound which may be non-invasively programmed through telemetry circuitry 44 and stored within the program memory 42 of the pacemaker. At the end of an escape interval an output stimulus is supplied to the heart through a pacing output amplifier 48 which is coupled to the patient's heart through a lead system 46. Likewise, sensed activity of the heart is detected through a sense amplifier 50 and is supplied to escape interval logic 40 for resetting the escape interval timer in a known fashion. The interaction of the programmable slope circuitry 37 and the slow waveform generator and voltage controlled oscillator are described in connection with Fig. 4. The programmable slope circuitry 37 receives

slope parameter information through non-invasive programming of the device. The slope parameter controls how rapidly the pacemaker will move from a lower or preset minimum rate to its maximum or upper rate. This, in essence, controls how rapidly the escape interval of the pacemaker will change in response to sensed activity. Three variations of the slope parameter are shown on the diagram of Fig. 4. When the slope parameter is set at its highest value there will be large increases or changes in the pacemaker's rate with the sensed activity of the patient while the pacemaker rate will change only over a small range if this slope parameter is set at its lowest level. This parameter permits the physician to control the interaction of the pacemaker with the patient.

Claims

1. A rate adaptive pacer (30) having a pulse generator for delivering stimulating pulses to cardiac tissue at the expiration of an escape interval, and including means (40) for altering the escape interval between preset limits in response to the sensed activity of the patient sensed through activity monitoring circuitry (32, 34, 36, 38), characterised in that said activity monitoring circuitry is responsive to the frequency of the peak spectral energy of mechanical forces external of the heart.

2. The pacer of claim 1 characterised in that said preset limits include upper and lower escape intervals which may be non-invasively altered through telemetry circuitry.

3. The pacer of claim 1 or 2 characterised in that said activity monitoring circuitry includes:

a sensor (32) located within the pacer for detecting force signals applied to the pacer by the interaction of the pacer and the patient's body; and

further including signal conditioning circuitry for extracting an activity parameter signal from said force signals.

4. The pacer of claim 3 characterised in that said sensor (32) comprises a piezoelectric transducer coupled to the external enclosure of said pacer for converting vibrational energy at the implant site to an electrical signal.

5. The pacer of claim 3 or 4 characterised in that said signal conditioning circuitry includes bandpass amplification means (34) for amplifying the output of said sensor for rejecting sensor frequency components below approximately 1 Hertz and above approximately 20 Hertz;

said bandpass amplification means being coupled to level detector means (34) for rejecting low amplitude components within the passband of said bandpass amplification means; and

said level detector means being coupled to voltage controlled oscillator means (38) for producing a pulse rate signal in dependence upon the frequency of the peak spectral energy within the passband of said bandpass amplifier means.

Patentansprüche

1. Frequenzadaptiver Schrittmacher (30) mit einem Impulsgenerator zum Anliefern von Reizimpulsen an Herzgewebe nach dem Verstreichen eines Escape-Intervalls, und mit einer Anordnung (40) zum Ändern des Escape-Intervalls zwischen vorgegebenen Grenzwerten aufgrund der über eine Aktivitätsüberwachungsschaltung (32, 34, 36, 38) erfaßten Aktivität des Patienten, dadurch gekennzeichnet, daß die Aktivitätsüberwachungsschaltung auf die Frequenz der Spitzenspektralenergie von mechanischen Kräften außerhalb des Herzens anspricht.

2. Schrittmacher nach Anspruch 1, dadurch gekennzeichnet, daß die vorgegebenen Grenzwerte obere und untere Escape-Intervalle einschließen, die sich über eine Telemetrieschaltung nichtinvasiv ändern lassen.

3. Schrittmacher nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Aktivitätsüberwachungsschaltung versehen ist mit:

einem innerhalb des Schrittmachers angeordneten Sensor (32) zum Ermitteln von Kraftsignalen, die an den Schrittmacher durch die Wechselwirkung zwischen dem Schrittmacher und dem Körper des Patienten angelegt werden; und

ferner eine Signalaufbereitungsschaltung vorgesehen ist, um aus den Kraftsignalen ein Aktivitätsparametersignal abzuleiten.

4. Schrittmacher nach Anspruch 3, dadurch gekennzeichnet, daß der Sensor (32) einen piezoelektrischen Wandler aufweist, der mit der äußeren Ummantelung des Schrittmachers gekoppelt ist, um Vibrationsenergie an der Implantationsstelle in ein elektrisches Signal umzuwandeln.

5. Schrittmacher nach Anspruch 3 oder 4, dadurch gekennzeichnet, daß die Signalaufbereitungsschaltung eine Bandpaß-Verstärkeranordnung (34) zum Verstärken des Ausgangssignals des Sensors unter Unterdrückung von Sensorfrequenzkomponenten unter etwa 1 Hertz und über etwa 20 Hertz aufweist;

wobei die Bandpaß-Verstärkeranordnung mit einer Pegeldetektoranordnung (34) zum Unterdrücken von innerhalb des Durchlaßbereiches der Bandpaß-Verstärkeranordnung liegenden Komponenten kleiner Amplitude versehen ist; und

die Pegeldetektoranordnung mit einer spannungsgesteuerten Oszillatoranordnung (38) zum Erzeugen eines Impulsfrequenzsignals in Abhängigkeit von der Frequenz der Spitzenspektralenergie innerhalb des Durchlaßbereichs der Bandpaß-Verstärkeranordnung gekoppelt ist.

Revendications

1. Stimulateur à fréquence adaptative (30) comportant un générateur d'impulsions propre à délivrer des impulsions de stimulation au tissu cardiaque à l'expiration d'un intervalle de sauvegarde, et comportant des moyens (40) propres à modifier l'intervalle de sauvegarde entre des

limites préréglées en réponse à l'activité détectée du patient, activité détectée par des circuits de surveillance d'activité (32, 34, 36, 38), caractérisé en ce que lesdits circuits de surveillance d'activité sont sensibles à la fréquence du pic d'énergie spectrale de forces mécaniques extérieures au coeur.

2. Stimulateur selon la revendication 1, caractérisé en ce que lesdites limites préréglées comprennent des intervalles de sauvegarde supérieur et inférieur qui peuvent être modifiés de manière non traumatisante grâce à un circuit de télémesure.

3. Stimulateur selon la revendication 1 ou 2, caractérisé en ce que lesdits circuits de surveillance d'activité comportent un capteur (32) disposé à l'intérieur du stimulateur pour détecter des signaux de force appliqués au stimulateur par l'interaction du stimulateur et du corps du patient; et comportant en outre des circuits de traitement de signaux propres à extraire un signal de paramètre d'activité desdits signaux de force.

4. Stimulateur selon la revendication 3, caractérisé en ce que ledit capteur (32) comprend un transducteur piézo-électrique couplé à l'enceinte externe dudit stimulateur pour convertir l'énergie vibratoire au site d'implantation en un signal électrique.

5. Stimulateur selon la revendication 3 ou 4, caractérisé en ce que lesdits circuits de traitement de signaux comportent des moyens d'amplification passe-bande (34) propres à amplifier le signal de sortie dudit capteur en rejetant les composantes de fréquence du capteur situées au-dessous d'environ 1 Hertz et au-dessus d'environ 20 Hertz; lesdits moyens d'amplification passe-bande étant couplés des moyens de détection de niveau (34) propres à rejeter les composantes de faible amplitude dans la bande passante desdits moyens d'amplification passe-bande; et lesdits moyens de détection de niveau étant couplés à des moyens d'oscillation à commande en tension (38) pour fournir un signal de fréquence d'impulsions sous la dépendance de la fréquence du pic d'énergie spectrale dans la bande passante desdits moyens d'amplification passe-bande.

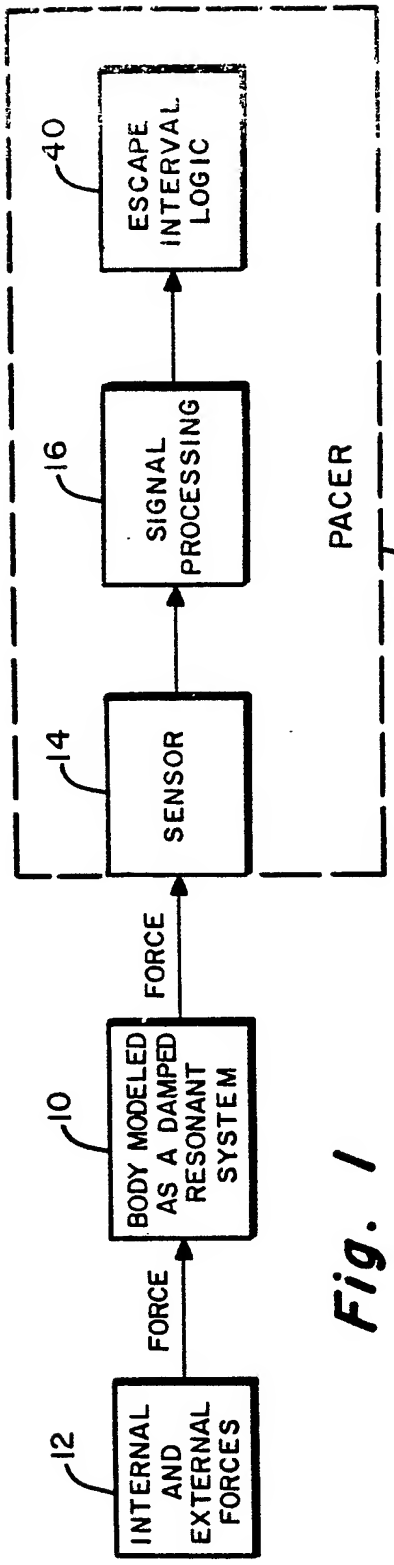
INTERNAL AND EXTERNAL FORCES
12
FORCE
BODY MODELED AS A DAMPED RESONANT SYSTEM
10
FORCE
SENSOR
14
SIGNAL PROCESSING
16
ESCAPE INTERVAL LOGIC
40
PACER
30

Fig. 1

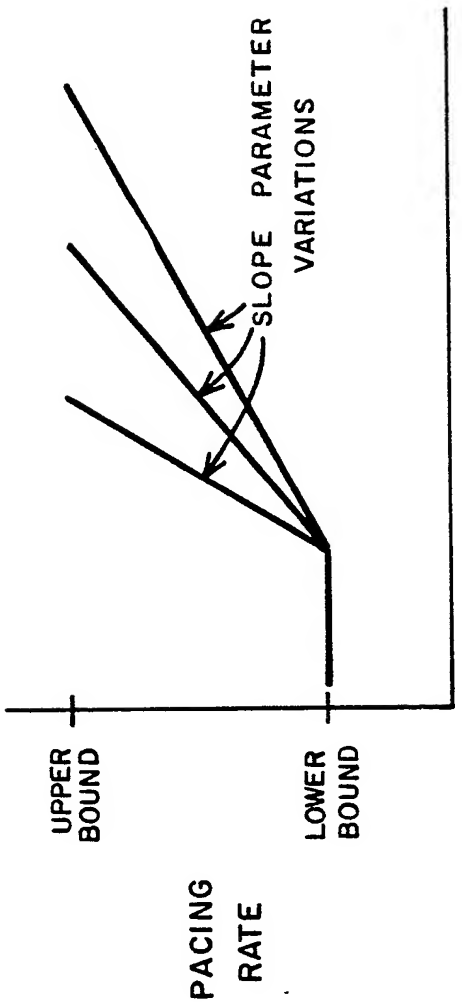
PACING RATE
UPPER BOUND
LOWER BOUND
SLOPE PARAMETER VARIATIONS
SENSED ACTIVITY

Fig. 4

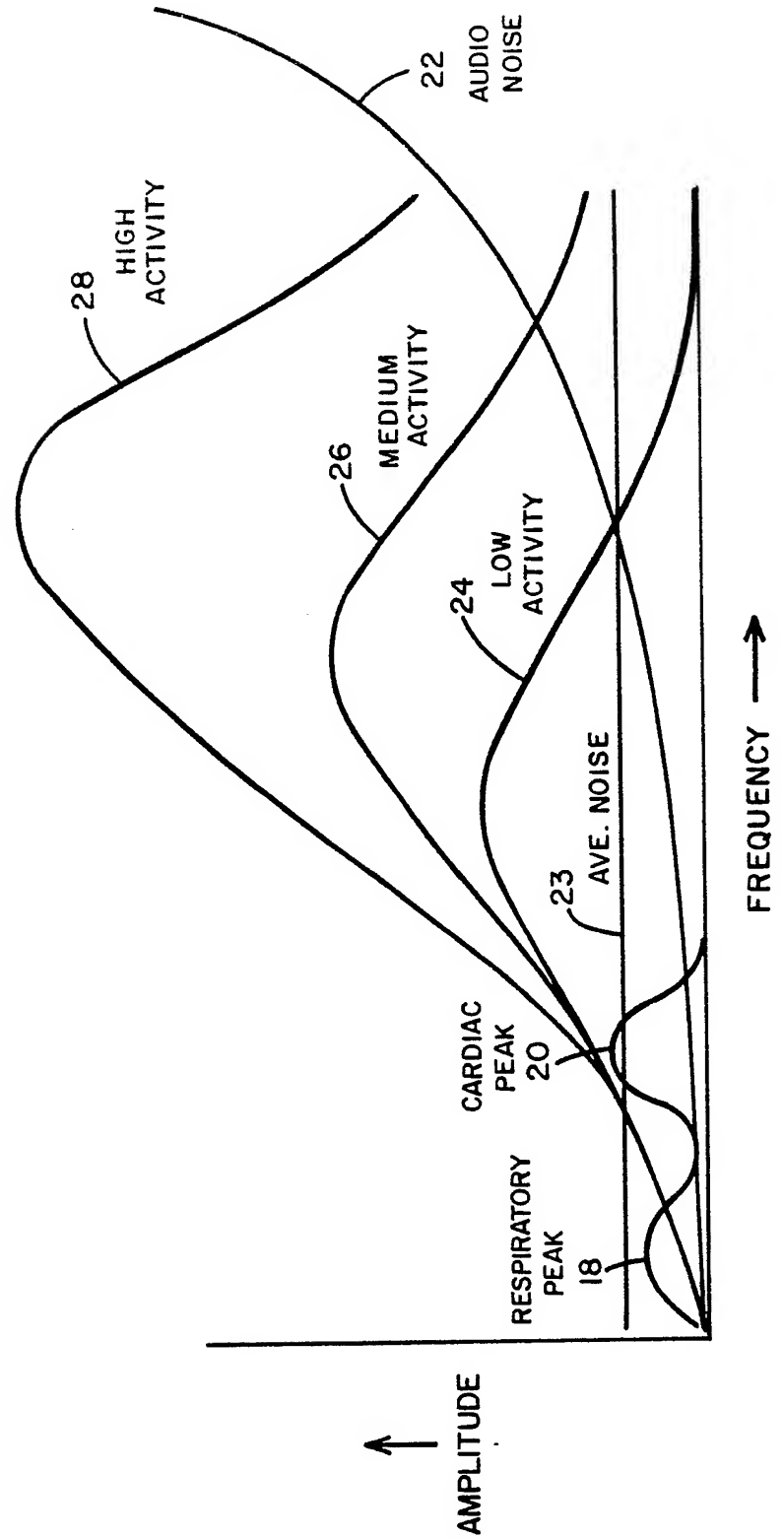
22
AUDIO
NOISE
28
HIGH
ACTIVITY
26
MEDIUM
ACTIVITY
24
LOW
ACTIVITY
23
AVE. NOISE
CARDIAC
PEAK
20
RESPIRATORY
PEAK
18
AMPLITUDE
FREQUENCY

Fig. 2

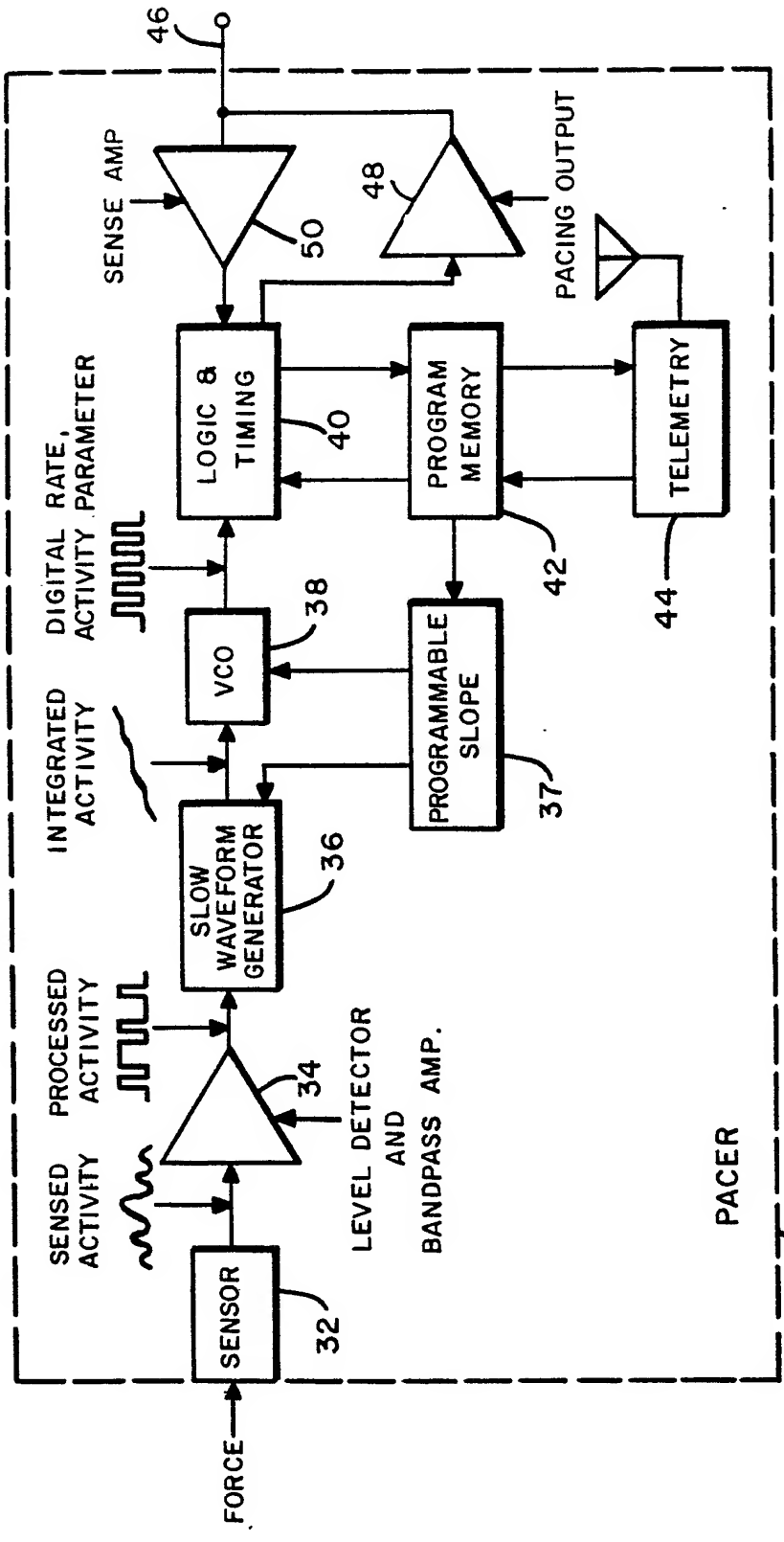
FORCE
SENSOR
32
SENSED ACTIVITY
PROCESSED ACTIVITY
LEVEL DETECTOR AND BANDPASS AMP.
34
SLOW WAVEFORM GENERATOR
36
INTEGRATED ACTIVITY
VCO
38
DIGITAL RATE, ACTIVITY PARAMETER
PROGRAMMABLE SLOPE
37
LOGIC & TIMING
40
PROGRAM MEMORY
42
TELEMETRY
44
PACER
30
SENSE AMP
50
48
PACING OUTPUT
46

Fig. 3

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(12) # NEW EUROPEAN PATENT SPECIFICATION

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(54) **Rate adaptive pacer.**

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T.C. Wong et al.: "Portable accelerometer device for measuring human energy expenditure", IEEE Transactions on Biomedical Engineering, Vol. BME-28, No. 6 (June 1981), pages 467-471

T. Bunge et al.: "Sensing internal and external body activities", in F. Perez-Gomez "Cardiac pacing: electrophysiology, tachyarrhythmia", Mount Kisco, N.Y. (1985), pages 786-791

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designated 30. The raw data from the sensor system 14 is supplied to signal processing circuitry 16 which develops an activity parameter which is applied to alter the escape interval logic 40. The nature of the signal processing circuitry is discussed in connection with Fig. 2.

Data has been collected which shows that the response of the typical human body which results from mechanical activity related to the physical activity of the patient such as pedal impacts from walking or running is centered around approximately 10 Hertz. The sensor 14 located within the pacer interacts with soft tissue at the implant site and detects the various mechanical vibrations present at that location. These forces result from the mechanical exertion of the patient which are related to the physiologic demand for oxygenated blood as well as a variety of noise signals resulting from respiration, cardiac activity, speaking and skeletal muscle noise.

In Fig. 2 there is shown a spectral analysis of the electrical signal from the sensor. Internal noise 18 due to respiration is centered at approximately 0.2 Hertz while the peak response 20 resulting from cardiac activity is centered at approximately 1.1 Hertz. Peak 18 lies below the general level of broad-band background noise 23 and peak 20 slightly exceeds it. Noise signals which result from audio signals in the patient's environment as well as noise due to the speech of the patient increase monotonically as shown by curve 22.

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As can be seen from the diagram the spectral peak of the low, medium and high activity curves shifts to the higher frequencies with higher activity levels. It is believed that this phenomenon is due to the upward shift of the spectrum of external mechanical excitation. This feature is important with respect to the signal processing parameters selected for the operation of the pacer of the present invention which is described in connection with Figs. 3 and 4.

Before leaving Fig. 2, it should be clear that the activity signals could be isolated from both high and low frequency noise sources through a filtering process which would attenuate both the respiratory, cardiac and audio components. The amplitude of this signal after bandpass filtration could be used as the activity parameter. However, it is believed that the use of such an activity parameter would be sensitive to the placement of the pacer and would be sensitive to the tissue characteristics surrounding the sensor at the implantation site. In recognition of this effect a zero-crossing detector effectively tracks the highest amplitude spectral component of the signal present within the passband of the sensor signal. Thus, it is important to note that the signal processing accomplished in block 16 of Fig. 1 first extracts the activity passband from low freqency cardiac and respiratory noise as well as separating the activity signal from high frequency audio noise. After appropriate bandpass filtering, the sensor signal is passed to a zero-crossing level detector which rejects all low amplitude signals within the passband. This feature permits the zero-crossing detector to track the spectral peak within the passband.

The level detector is followed by a circuit for producing a pulse rate signal proportional to the frequency of the peak spectral components within the activity passband. This signal is utilized by the pacemaker circuitry for altering the escape interval of the pacer.

This system is capable of extracting a meaningful indication of the physical activity of the patient from a sensor located within the pacemaker can. One application of this sensed activity parameter to a cardiac pacemaker is to utilize the activity parameter to slowly vary the rate between a programmable or preset upper and lower rate. The implementation of such a system is described in connection with Fig. 3.

In Fig. 3, the pacemaker is designated generally 30. The pacer includes a piezoelectric force sensor 32 coupled to the hermetic enclosure of the pacemaker for converting vibrational energy at the pacemaker site into a sensed activity signal. The sensed activity signal is applied to a bandpass amplifier which rejects the low and high frequency components of the applied force. This signal is also level detected producing a processed activity signal which excludes low amplitude information within the designated passband of the bandpass amplifier. This function is accomplished within circuit element 34. The processed activity signal produced by circuit element 34 is supplied to a slow waveform generator 36 which integrates this activity over a selectable time period selected by programmable slope control 37. The output of the slow waveform generator is applied to the voltage input of a volt-

age controlled oscillator 38 converting the integrated activity signal into a pulse rate proportional to the magnitude of the activity parameter. This activity parameter signal is supplied to the logic and timing circuitry of a conventional demand pacemaker 40 for altering the escape interval. The details of the implementation of the escape interval alteration circuitry are not provided since they are within the skill of pacemaker designers.

The escape interval may vary between an upper and lower bound which may be non-invasively programmed through telemetry circuitry 44 and stored within the program memory 42 of the pacemaker. At the end of an escape interval an output stimulus is supplied to the heart through a pacing output amplifier 48 which is coupled to the patient's heart through a lead system 46. Likewise, sensed activity of the heart is detected through a sense amplifier 50 and is supplied to escape interval logic 40 for resetting the escape interval timer in a known fashion. The interaction of the programmable slope circuitry 37 and the slow waveform generator and voltage controlled oscillator are described in connection with Fig. 4. The programmable slope circuitry 37 receives slope parameter information through non-invasive programming of the device. The slope parameter controls how rapidly the pacemaker will move from a lower or preset minimum rate to its maximum or upper rate. This, in essence, controls how rapidly the escape interval of the pacemaker will change in response to sensed activity. Three variations of the slope parameter are shown on the diagram of Fig. 4. When the slope parameter is set at its highest value there will be large increases or changes in the pacemaker's rate with the sensed activity of the patient while the pacemaker rate will change only over a small range if this slope parameter is set at its lowest level. This parameter permits the physician to control the interaction of the pacemaker with the patient.

Claims

1. A rate adaptive pacer (30) having a pulse generator for delivering stimulating pulses to cardiac tissue at the expiration of an escape interval, and including means (40) for altering the escape interval between preset limits in response to the sensed activity of the patient sensed through activity monitoring circuitry (32, 34, 36, 38), characterised in that said activity monitoring circuitry tracks the frequency of the peak spectral energy of mechanical forces external of the heart.

2. The pacer of claim 1 characterised in that said preset limits include upper and lower escape intervals which may be non-invasively altered through telemetry circuitry.

3. The pacer of claim 1 or 2 characterised in that said activity monitoring circuitry includes:

   a sensor (32) located within the pacer for detecting force signals applied to the pacer by the interaction of the pacer and the patient's body; and

   further including signal conditioning circuitry for extracting an activity parameter signal from said force signals.

4. The pacer of claim 3 characterised in that said sensor (32) comprises a piezoelectric transducer coupled to the external enclosure of said pacer for converting vibrational energy at the implant site to an electrical signal.

5. The pacer of claim 3 or 4 characterised in that said signal conditioning circuitry includes bandpass amplification means (34) for amplifying the output of said sensor for rejecting sensor frequency components below approximately 1 Hertz and above approximately 20 Hertz;

   said bandpass amplification means being coupled to level detector means (34) for rejecting low amplitude components within the passband of said bandpass amplification means; and

   said level detector means being coupled to voltage controlled oscillator means (38) for producing a pulse rate signal in dependence upon the frequency of the peak spectral energy within the passband of said bandpass amplifier means.

Patentansprüche

1. Frequenzadaptiver Schrittmacher (30) mit einem Impulsgenerator zum Anliefern von Reizimpulsen an Herzgewebe nach dem Verstreichen eines Escape-Intervalls, und mit einer Anordnung (40) zum Ändern des Escape-Intervalls zwischen vorgegebenen Grenzwerten aufgrund der über eine Aktivitätsüberwachungsschaltung (32,34,36,38) erfaßten Aktivität des Patienten, dadurch gekennzeichnet, daß die Aktivitätsüberwachungsschaltung die Frequenz der Spitzenspektralenergie von mechanischen Kräften außerhalb des Herzens verfolgt.

2. Schrittmacher nach Anspruch 1, dadurch gekennzeichnet, daß die vorgegebenen Grenzwerte obere und untere Escape-Intervalle einschließen, die sich über eine Telemetrieschaltung nichtinvasiv ändern lassen.

3. Schrittmacher nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Aktivitätsüberwachungsschaltung versehen ist mit:
einem innerhalb des Schrittmachers angeordneten Sensor (32) zum Ermitteln von Kraftsignalen, die an den Schrittmacher durch die Wechselwirkung zwischen dem Schrittmacher und dem Körper des Patienten angelegt werden, und
ferner eine Signalaufbereitungsschaltung vorgesehen ist, um aus den Kraftsignalen ein Aktivitätsparametersignal abzuleiten.

4. Schrittmacher nach Anspruch 3, dadurch gekennzeichnet, daß der Sensor (32) einen piezoelektrischen Wandler aufweist, der mit der äußeren Ummantelung des Schrittmachers gekoppelt ist, um Vibrationsenergie an der Implantationsstelle in ein elektrisches Signal umzuwandeln.

5. Schrittmacher nach Anspruch 3 oder 4, dadurch gekennzeichnet, daß die Signalaufbereitungsschaltung eine Bandpaß-Verstärkeranordnung (34) zum Verstärken des Ausgangssignals des Sensors unter Unterdrückung von Sensorfrequenzkomponenten unter etwa 1 Hertz und über etwa 20 Hertz aufweist; wobei die Bandpaß-Verstärkeranordnung mit einer Pegeldetektoranordnung (34) zum Unterdrükken von innerhalb des Durchlaßbereiches der Bandpaß-Verstärkeranordnung liegenden Komponenten kleiner Amplitude versehen ist; und
die Pegeldetektoranordnung mit einer spannungsgesteuerten Oszillatoranordnung (38) zum Erzeugen eines Impulsfrequenzsignals in Abhängigkeit von der Frequenz der Spitzenspektralenergie innerhalb des Durchlaßbereichs der Bandpaß-Verstärkeranordnung gekoppelt ist.

Revendications

1. Stimulateur à fréquence adaptative (30) comportant un générateur d'impulsions propre à délivrer des impulsions de stimulation au tissu cardiaque à l'expiration d'un intervalle de sauvegarde, et comportant des moyens (40) propres à modifier l'intervalle de sauvegarde entre des limites préréglées en réponse à l'activité détectée du patient, activité détectée par des circuits de surveillance d'activité (32, 34, 36, 38), caractérisé en ce que lesdits circuits de surveillance d'activité suivent la fréquence du pic d'énergie spectrale de forces mécaniques extérieures au coeur.

2. Stimulateur selon la revendication 1, caractérisé en ce que lesdites limites préréglées comprennent des intervalles de sauvegarde supérieur et inférieur qui peuvent être modifiés de manière non traumatisante grâce à un circuit de télémesure.

3. Stimulateur selon la revendication 1 ou 2, caractérisé en ce que lesdits circuits de surveillance d'activité comportant un capteur (32) disposé à l'intérieur du stimulateur pour détecter des signaux de force appliqués au stimulateur par l'interaction du stimulateur et du corps du patient ; et comportant en outre des circuits de traitement de signaux propres à extraire un signal de paramètre d'activité desdits signaux de force.

4. Stimulateur selon la revendication 3, caractérisé en ce que ledit capteur (32) comprend un transducteur piézo-électrique couplé à l'enceinte externe dudit stimulateur pour convertir l'énergie vibratoire au site d'implantation en un signal électrique.

5. Stimulateur selon la revendication 3 ou 4, caractérisé en ce que lesdits circuits de traitement de signaux comportent des moyens d'amplification passe-bande (34) propres à amplifier le signal de sortie dudit capteur en rejetant les composantes de fréquence du capteur situées au-dessous d'environ 1 Hertz et au-dessus d'environ 20 Hertz ; lesdits moyens d'amplification passe-bande étant couplés à des moyens de détection de niveau (34) propres à rejeter les composantes de faible amplitude dans la bande passante desdits moyens d'amplification passebande ; et lesdits moyens de détection de niveau étant couplés à des moyens d'oscillation à commande en tension (38) pour fournir un signal de fréquence d'impulsions sous la dépendance de la fréquence du pic d'énergie spectrale dans la bande passante desdits moyens d'amplification passebande.

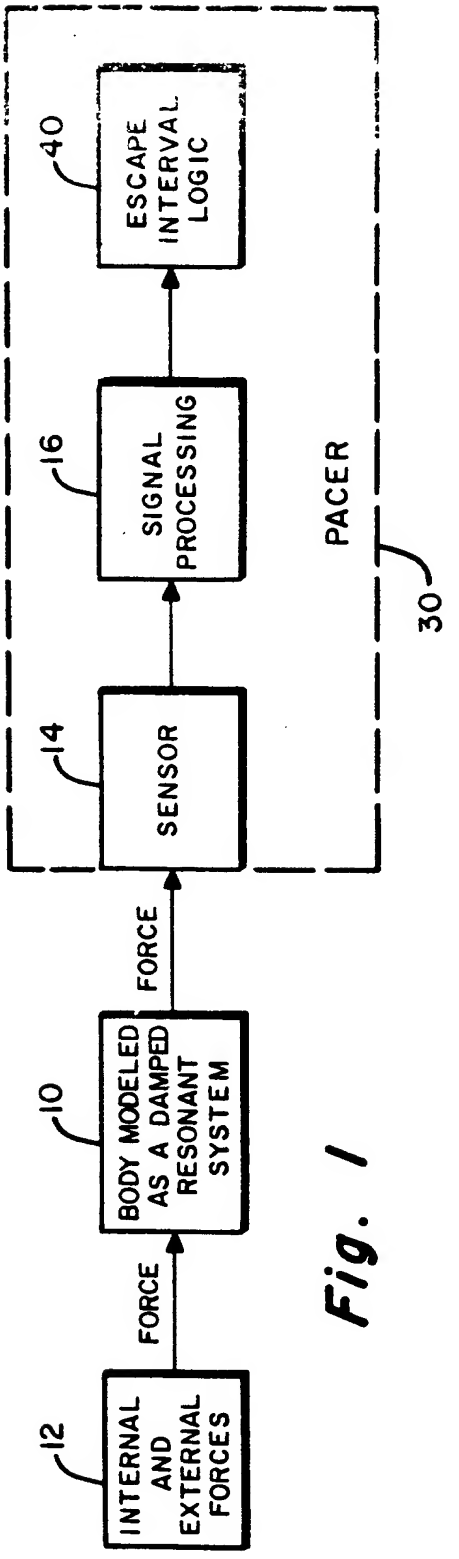
12
INTERNAL AND EXTERNAL FORCES
FORCE
10
BODY MODELED AS A DAMPED RESONANT SYSTEM
FORCE
14
SENSOR
16
SIGNAL PROCESSING
40
ESCAPE INTERVAL LOGIC
PACER
30

Fig. 1

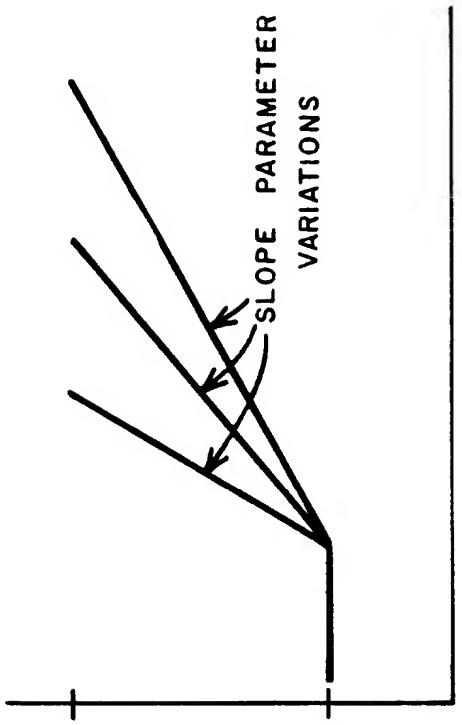
UPPER BOUND
LOWER BOUND
PACING RATE
SLOPE PARAMETER VARIATIONS
SENSED ACTIVITY

Fig. 4

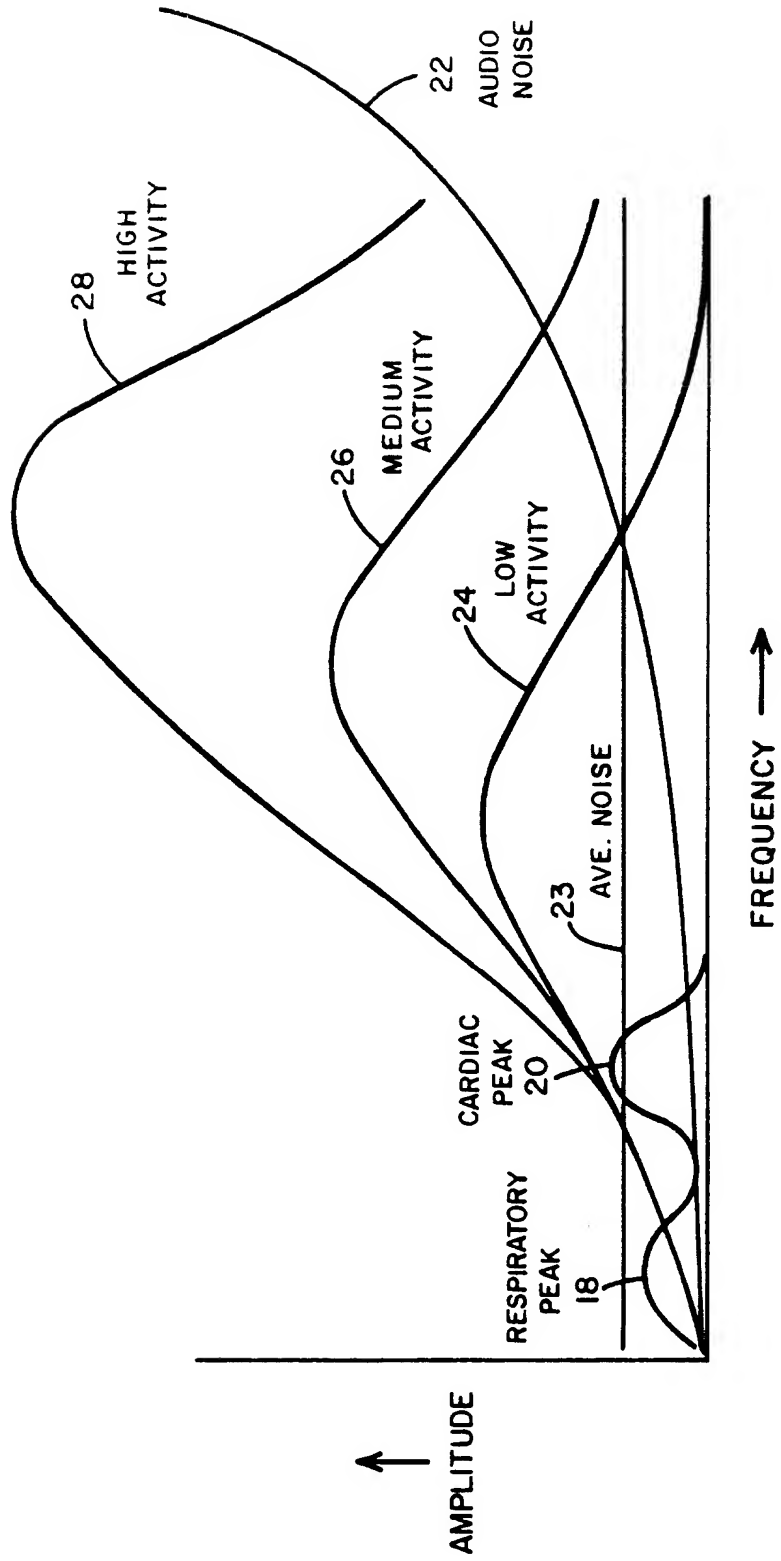
AMPLITUDE
FREQUENCY
RESPIRATORY PEAK
18
CARDIAC PEAK
20
AVE. NOISE
23
LOW ACTIVITY
24
MEDIUM ACTIVITY
26
HIGH ACTIVITY
28
AUDIO NOISE
22

Fig. 2

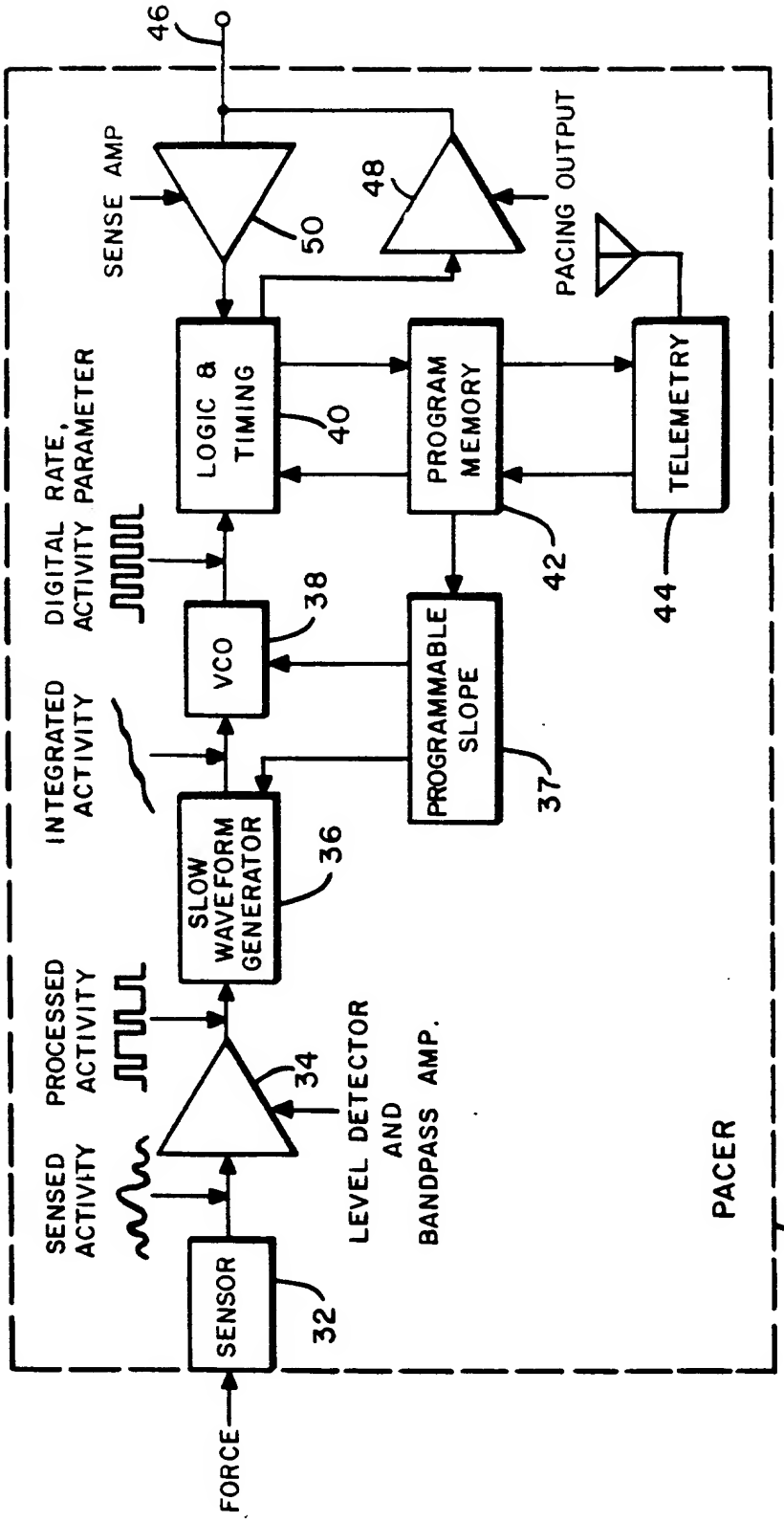
FORCE
SENSOR
32
SENSED ACTIVITY
PROCESSED ACTIVITY
34
LEVEL DETECTOR AND BANDPASS AMP.
SLOW WAVEFORM GENERATOR
36
INTEGRATED ACTIVITY
VCO
38
DIGITAL RATE, ACTIVITY PARAMETER
PROGRAMMABLE SLOPE
37
LOGIC & TIMING
40
PROGRAM MEMORY
42
TELEMETRY
44
PACER
30
SENSE AMP
50
46
48
PACING OUTPUT

Fig. 3